C H A P T E R 1 7

Audio Components

This chapter presents the PC 99 requirements and recommendations for audio devices.

Contents

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Introduction to PC 99 Audio

The PC 99 audio basic requirements are designed to identify the baseline operating system and hardware audio support available for existing and emerging multimedia applications. They are also designed to ensure that a minimum audio capability exists across a majority of platforms.

The advanced recommendations describe additional software and hardware features beyond the minimum requirements. These recommendations support vertical applications and provide scalability above the baseline audio capabilities by offering higher compatibility, performance, concurrency, or quality.

WDM and PC Audio. One key to the successful advancement of audio in the PC is WDM Audio class support. The architecture performs all audio processing in kernel mode, which significantly improves latency. WDM provides standardized interfaces for non-Microsoft code to run in kernel mode, facilitating the development of host algorithms from multiple vendors.

WDM also provides a more complete architecture than previous generations. Code common to all audio hardware on a given bus is now part of the operating system, making for faster development with more consistent results. WDM promises to streamline development through the integration of the Windows and Windows NT driver models. Now, the same driver will work under both operating systems.

External Digital Audio. USB and IEEE 1394 provide excellent mechanisms for delivering digital audio to external peripherals for high-quality conversion (greater than 85 dB dynamic range) to and from analog. In the near term, the popularity of USB makes it a natural choice. In the long term, the consumer-electronics industry envisions IEEE 1394 transporting audio and video among many devices in a simple, high-performance manner.

PC Audio Transitions

Throughout 1998 and 1999, audio in the PC will continue to offer a wide array of possibilities. One notable trend is the movement toward solutions that use a hybrid of host-based and device-based processing of audio data. Current and future versions of the DirectX APIs, including DirectSound, DirectSound3D, and DirectMusic, will expand the degree of support for all styles of audio solutions, from host-based to entirely hardware-based.

As the PC is increasingly called upon to play the part of a consumer-electronics device (for example, video-disc playback), sound quality becomes more important. A number of initiatives are underway to achieve optimal sound quality. Another implication of this trend is the need for simpler operation and hardware configuration.

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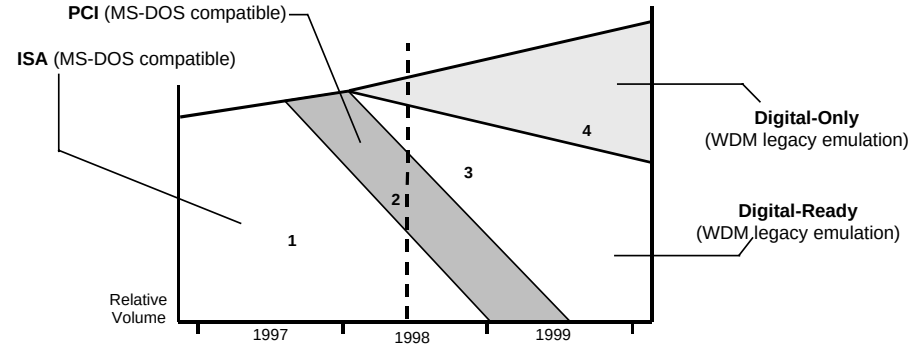
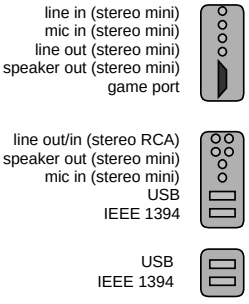
The state of audio functionality is far from stagnant, presenting a challenge for the industry to maximize performance and simplicity, and to add more advanced features. This chapter will focus on how and when this can be done.

The shift to higher quality and support for external digital connectivity will not happen overnight. One objective of PC 99 Audio is to facilitate the transition over the next few years. The remainder of this section is a summary of the projected evolution of PC audio.

The following figure demonstrates that by mid-1998, four viable audio solutions will exist in the PC marketplace. The figure also projects the estimated market share for each solution over the next three years.



Key and Example Port Configurations:



1. **ISA** (MS-DOS compatible)
   - Legacy hardware solution on a single chip with Sound Blaster, FM synthesis, MIDI UART, and game port
2. **PCI** (MS-DOS compatible)
   - Legacy hardware, wavetable MIDI, DirectSound3D
3. **Digital-Ready** (WDM legacy emulation)
   - PCI or integrated controller
   - Optional PCI-based, WDM-compatible acceleration
   - Choice of analog or external connector (USB or IEEE 1394), or both
4. **Digital-Only** (WDM legacy emulation)
   - Host-based audio processing with legacy emulation
   - Optional PCI-based, WDM-compatible acceleration
   - USB or IEEE 1394 peripherals only

Digital Audio Migration

The following explains the marketplace options illustrated in the previous figure:

- **ISA (legacy MS-DOS–compatible).** These are mature, low-cost, single-chip implementations that deliver support for Sound Blaster registers and mixing, Yamaha OPL-compatible frequency modulation (FM) synthesis, MPU 401 MIDI UART, and game port. Each is fully Plug and Play-compatible.
- **PCI (legacy MS-DOS–compatible).** The majority of PCI implementations are two-chip split digital/analog system-board or add-on designs based on

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Audio Codec ’97 architecture. Many of these designs incorporate hardware support for legacy ISA devices using PC/PCI DMA, distributed DMA (DDMA), or other similar techniques, and are fully Plug and Play-compatible. Many also support high-quality wave table MIDI synthesis and DirectX acceleration.

- **PCI (digital ready).** The current generation of PCI-based designs have the potential to deliver WDM-compatible audio acceleration that can be part of a filter graph targeting either a built-in audio codec or an external USB codec for output. These designs have the option of leveraging the WDM legacy emulation capabilities or incorporating hardware legacy compatibility. A digital-ready PC can support mixed configuration of analog and/or digital peripherals.
- **USB (digital only).** These systems eliminate all built-in audio rendering resources and use external USB speakers and microphones for audio I/O. Hardware acceleration can be provided by WDM-compatible PCI devices.

The following factors will determine which of the previously listed audio solutions are suitable in 1998:

- Cost. The total bill of materials for PCI, USB, and IEEE 1394 solutions, including microphone and speakers.
- Compatibility. The desired level of legacy MS-DOS–based game compatibility.
- Quality. The system output dynamic range and total harmonic distortion plus noise (THD+N) performance necessary to meet specific market requirements.
- Performance. Dependent on the choice of host processor, audio bus (PCI, USB, or IEEE 1394), and system audio hardware acceleration features, such as Downloadable Sounds (DLS) wave-table MIDI synthesis and multistream Head Related Transfer Function (HRTF) 3-D.

Four audio applications merit more detailed discussion and are described in the following sections:

- Scalable audio for 3-D games
- Scalable music synthesis for games and multimedia
- CD and DVD media playback
- Full-duplex H.323/H.324 video and audio conferencing

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Scalable Audio for 3-D Games

The APIs provide standard interfaces for applications to utilize eight or more streams of 3-D-positioned audio. The DirectSound3D Hardware Emulation Layer (HEL) enables optimal configuration based on CPU performance and installed hardware and enables three levels of 3-D support:

- Software-simulated 3-D using simple inter-aural delay processing
- True HRTF 3-D filtering at 22.05 kHz optimized for Intel MMX™ technology
- Hardware acceleration

WDM audio supports the following features specifically for 3-D games under Windows 98 and Windows NT 5.0:

- Software emulation of legacy hardware to support MS-DOS-based games in Windows 98. WDM drivers, which run in kernel mode, provide virtual Sound Blaster Pro, MPU 401, and legacy joystick interfaces.

  Direct access to audio hardware has never been supported in Windows NT, and the WDM audio services for Windows NT do not include support for MS-DOS-based games.

Note: **Preliminary test data on the level of compatibility achieved for approximately 100 best-selling MS-DOS-based game titles will be available from Intel in March 1998. Better than 90 percent compatibility is expected.**

- A standard interface for the application to provide multiple streams of 3-D–positioned audio. DirectSound3D supports software-simulated 3-D (via inter-aural delay processing) and true HRTF 3-D processing at 22.05 kHz, or hardware acceleration. The architecture supports optimal configuration based on CPU performance and installed hardware.
- A wave-table General MIDI synthesizer entirely in kernel-mode software. This provides 24 voices of music synthesis with 22.05-kHz output. DirectShow, DirectMusic, WINMM, and virtual MPU 401 can use the synthesizer functions. The architecture supports optimal configuration based on CPU performance and installed hardware.
- A high-quality kernel-mode software SRC capability, which converts data streams (including composite mixes of all 11.025-kHz or 22.05-kHz sources) to the final output mix format, typically 16-bit 44.1 kHz (general SRC support includes other rates).

  Note: The kernel mixer policy is documented at the following URL: TBD.
- A kernel-mode system-wide software mixer, which supports DirectSound, DirectShow, and WINMM clients, plus kernel-mode WDM filters, including Red Book CD-ROM and MIDI drivers. The mixer implements highly

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optimized, same sample rate PCM mixing at 8-bit or 16-bit 11.025, 22.05, 44.1, and 48 kHz (general mixing support includes other formats).

Note: The kernel mixer policy is documented at the following URL: TBD.

- Flexible control of the output destination. The WDM drivers can send the master 16-bit 44.1-kHz or 48-kHz or other format output to a PCI, USB, or IEEE 1394 audio device. Additionally, support is provided for redirection of PCI-device final-mix output to USB speakers.

The minimum PC 99 audio hardware support necessary for 3-D games is built-in or external audio codec support for playback of 16-bit stereo PCM data at a 44.1-kHz sample rate. For a list of the PC 99 requirements, see the "Basic Audio Requirements" section later in this chapter.

The system designer might choose to include the following optional software or hardware in order to provide additional capabilities:

- Optimized software or digital-ready, hardware acceleration for higher quality or concurrency DLS wave-table MIDI synthesis, with associated mixing and SRC support
- Optimized software or digital-ready hardware acceleration for higher concurrency HRTF 3-D positional audio, with associated mixing and SRC support

The following table presents actual measurements collected by Intel Architecture Labs (IAL) for scalable audio for 3-D games on Intel Pentium II processors with Intel MMX technology.

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Performance Measurements for Scalable Audio for 3-D Games

Function	233-MHz Pentium II processor[1]
Wave-table MIDI synthesis, 24 voices at 22.05 kHz	5%
Mixing with pan and volume for simulated 3-D, eight stereo streams at 22.05 kHz	3%
SRC, upsampling of the stereo composite mix of all 22.05-kHz sources to 44.1 kHz	2%
Audio effects (reverb, tone, or pseudo 3-D), stereo at 44.1 kHz	2%
Audio sample transport to PCI or USB codec	2–4%
Total with software simulated 3-D	**14–16%**
HRTF 3-D with cross-talk cancellation for speakers, eight streams at 22.05 kHz	12%[2]
Total with true optimized software HRTF 3-D	**23–25%**

[1] Actual performance is dependent on specific processor, chip-set, memory, and I/O subsystem implementations, as well as the software implementation (integer, floating point [FP], or MMX technology). To estimate the performance on other processor speeds with MMX technology, use a ratio based on the processor's MHz rating.

[2] HRTF 3-D performance is based on the 3Q1997 release of Intel 3D Realistic Sound eXperience (RSX).

Scalable Music Synthesis for Games and Multimedia

DirectMusic is a new set of core services featuring:

- An interactive music engine that enables the PC to generate a highly customized musical accompaniment capable of following on-screen action with precision.
- An open architecture that provides custom sound sets that can be played back on music products from any manufacturer.
- MIDI APIs that provide much better timing and control of musical streams.

DirectMusic will be included in the initial shipment of Windows NT 5.0 and will be available as an add-on for Windows 98 and Windows 95. To obtain more information on DirectMusic and the interactive music architecture, visit http://www.microsoft.com/directx/. The details of DirectMusic of interest to hardware manufacturers include the following:

- An API that allows applications to manage DLS files and download the relevant instruments to hardware or software synthesizers. For more information, see *DLS Specification, Version 1.0* or later, at http://www.midi.org.

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- A software synthesizer to accommodate situations where no hardware capability exists. The architecture allows third-party software synthesizers to connect with DirectMusic.
- A new timing model with a kernel-mode sequencer that allows the components to track either a system clock or the sample clock on the audio hardware. There is also a provision for the synthesizer to report latency and subsequently receive MIDI data with the appropriate advanced-scheduling. As a result, hardware and software synthesizers will play completely in sync.
- A decompression model that enables developers to encode DLS files using any of the ACM codecs. The system performs real-time decompression of the file before making it available to the hardware or software synthesizer.

Because of the availability of a software synthesizer, PC 99 does not require hardware to support DirectMusic. To create a more efficient implementation with higher performance, the hardware designer needs to address the following trade-offs:

- CPU utilization vs. hardware cost. Hardware synthesizers ~~will~~ typically consume fewer system resources during playback of a DirectMusic application.
- Sound quality vs. hardware cost. Hardware synthesizers typically operate at a higher master sample rate and use higher-order interpolation than software synthesizers.

CD and DVD Media Playback

WDM audio supports the following features for CD and DVD media playback under the Windows 98 and Windows NT 5.0 operating systems:

- A kernel-mode CD-ROM driver that emulates MSCDEX commands and implements reading, parsing, and streaming of Red Book CD digital audio to the kernel-mode WDM system-wide mixer at 16-bit stereo 44.1 kHz.
- A Universal Disk Format (UDF) DVD file reader, splitter, and navigator that provides access for DirectShow clients to separate video and audio streams.
- A kernel-mode, system-wide software mixer, which supports DirectSound, DirectShow, and WINMM clients, plus kernel-mode WDM filters, including Red Book CD-ROM and MIDI drivers. The architecture provides the ability for algorithms from any vendor to decode the DVD audio, and it supports mixing at 16-bit stereo 48 kHz.
- Flexible control of the output destination. The WDM drivers can send the master 16-bit 44.1-kHz or 48-kHz or other format output to a PCI, USB, or IEEE 1394 audio device. Additionally, support is provided for redirection of the PCI-device final-mix output to USB speakers.

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Baseline PC 99 audio hardware support for CD-ROM and DVD media playback requires that the built-in or external audio codec support playback of 16-bit stereo PCM data at either a 44.1-kHz or 48-kHz sample rate. For a list of the PC 99 requirements, see the "Basic Audio Requirements" section later in this chapter.

For MPEG content, the system designer might choose to include optional DirectShow or WDM kernel-mode streaming filter components or hardware that can provide the following capabilities:

- Greater than 85-dB dynamic range codec audio quality to ~~the~~ meet performance requirements of the consumer-electronics market
- Software or hardware Dolby AC-3 or MPEG-2 multichannel decode and downmix to stereo at 16-bit 48 kHz
- Software or hardware MPEG-1 layer-2 stereo at 16-bit 32, 44.1, or 48 kHz
- Software or hardware support for up to 24-bit 96-kHz linear PCM (LPCM) data, down-converted to 16-bit 48 kHz

The following table presents actual measurements collected by IAL for software Dolby AC-3 decode on Intel Pentium II processors with MMX technology.

Performance Measurements for Dolby AC-3 Decode

Function	233-MHz Pentium II processor[1]
Dolby-certified 5.1-channel AC-3 decode and downmix to ProLogic-encoded stereo at 48 kHz	8%
Optional Dolby-certified virtual surround for rear channels, two channels at 48 kHz	12%[2]
Total for AC-3 decode with optimized software HRTF 3-D virtual surround	**20%**

[1] Actual performance is dependent on specific processor, chip-set, memory, and I/O subsystem implementations, as well as the software implementation (integer, FP, or MMX technology). To estimate the performance on other processor speeds with Intel MMX technology, use a ratio based on the processor's MHz rating.

[2] HRTF 3-D virtual surround performance is based on 3Q1997 release of Intel 3D RSX.

Full-Duplex H.323/H.324 Video and Audio Conferencing

WDM audio supports the following features for full-duplex video and audio conferencing under Windows 98 and Windows NT 5.0:

- Native 32-bit DirectSound support for simultaneous audio input and output, not dependent on 16-bit MMSYS components.
- Input and output position reporting mechanisms for synchronization of speaker and microphone streams, accurate to 1 ms or better.

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- WDM Stream class driver that provides access to acoustic echo cancellation (AEC) reference interfaces supported by hardware codecs.
- WDM system audio filter graph that supports insertion of a non-Microsoft kernel-mode AEC filter module adjacent to the WDM Stream class driver in both the input and output streams.

Baseline PC 99 audio hardware support for H.323/H.324 video and audio conferencing requires full-duplex audio capability. For a list of the PC 99 requirements, see the "Basic Audio Requirements" section later in this chapter.

The system designer might choose to include optional hardware to provide hardware AEC references for echo cancellation filtering.

The following table presents actual measurements collected by IAL for H.323/H.324 audio on Intel Pentium II processors with MMX technology.

Performance Measurements for H.323/H.324 Audio

Function	233-MHz Pentium II processor[1]
Full-duplex G.723.1 encode and decode, mono at 8 kHz	10%
Full-duplex AEC, mono at 8 kHz	6%
Total H.323/H.324 audio	**16%**

[1] Actual performance is dependent on specific processor, chip-set, memory, and I/O subsystem implementations, as well as the software implementation (integer, FP, or MMX technology). To estimate the performance on other processor speeds with Intel MMX technology, use a ratio based on the processor's MHz rating.

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Basic Audio Requirements

This section defines basic PC 99 hardware feature requirements for audio components. These are system-based requirements, targeted for the entire PC solution as it ships, regardless of whether the audio components are separate add-on devices or are built into the system (for example, on the system board or the video monitor).

System Requirements for Audio

This section summarizes the PC 99 system requirements for audio.

1. PC system includes PC 99 audio capabilities

Consumer PC 99	*Office PC 99*	*Entertainment PC 99*
Recommended	*Recommended*	*Required*

[Note to Reviewers: Input is requested on upgrading PC 99 audio support to a requirement for Consumer PCs, either desktop and/or mobile. Any relevant data regarding consumer demand for audio support is welcomed.

Although audio is a standard feature in most PC market segments, it is understood that certain SOHO and Office PC designs that focus heavily on cost will not require audio. For PCs that include audio, the requirements defined in this chapter must be met.

2. Audio device does not connect to ISA bus

Consumer PC 99	*Office PC 99*	*Entertainment PC 99*
Required	*Required*	*Required*

In 1999, the transition away from ISA will be complete. Some of the reasons that ISA is not acceptable include the high overhead of transferring audio samples, the excessive requirements of resources such as IRQs, DMA, and I/O, plus limited power management capabilities.

3. Audio device does not use legacy hardware interfaces in an MS-DOS box

Consumer PC 99	*Office PC 99*	*Entertainment PC 99*
Required	*Required*	*Required*

If the audio device supports MS-DOS applications, it must use operating system-provided or operating system-compatible software emulation of legacy interfaces when in an MS-DOS box. Use of any legacy ~~hardware~~ technique in which applications communicate directly with ~~utilize~~ ISA IRQ, DMA, or IO hardware resources, such as PC/PCI or DDMA, in an MS-DOS box does not meet PC 99 requirements. Support for legacy hardware techniques in real-mode MS-DOS, Windows 3.1, or Windows 95 is acceptable, as long as it does not interfere with Windows 98 operation.

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Continued support for direct access to legacy audio hardware prevents Windows from supporting multiple simultaneous audio clients, introduces potential resource conflicts, and degrades overall system performance.

With the elimination of ISA, the PC finally has the opportunity to move away from the model where hardware uses a very limited selection of resources. Even with the advent of Plug and Play, legacy audio hardware still has a high likelihood of an irreconcilable conflict. Given that a typical legacy interface requires two DMA channels, two IRQ selections, and more than four I/O register sets, it is highly probable that either there is a conflict with other hardware—or that a relevant MS-DOS application cannot accommodate the current selection.

Software emulation avoids the problems of legacy hardware in two respects. First, because it uses "virtual" resources, it avoids conflicts with other hardware. Second, software emulation avoids the awkwardness of a PCI device trying to allocate ISA resources—which necessitates dependencies on core logic chip sets and BIOS.

To make PCs easier to use, PC 99 requires that legacy hardware interfaces not impact the Windows experience. The majority of users have neither the desire nor the sophistication to manipulate legacy resources. For those that do, Windows 98 offers real-mode MS-DOS. In this mode, users can return to the era where they had complete control and responsibility for their machine's hardware configuration.

Audio Performance and Feature Requirements

This section summarizes the required performance and features for audio on PC 99 systems.

Several companies have joined together to develop a standardized testing procedure for defining and measuring audio performance titled "Personal Computer Audio Quality Measurement" (PCAQM), available on the web site at http://www.microsoft.com/hwdev/.

Note to Reviewers: The PCAQM definitions and test methods are currently available at the following URL: http://www.cirrus.com/products/papers/meas/meas.html

Contributors to the~~is~~ PCAQM specification include Audio Precision, Compaq Computer Corporation, Crystal Semiconductor, Intel Corporation, and Microsoft Corporation.

Microsoft WHQL test procedures are based on this methodology and are available at http://www.microsoft~~/~~.com/hwtest/.

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Note to Reviewers: The WHQL test methods are currently at the following URL: http://www.microsoft.com/hwtest/faqs/FAQ_Audio.stm#B

4. Audio performance meets PC 99 requirements

Required

The following table summarizes audio performance requirements for all audio-enabled PC 99 systems, with the exceptions noted for mobile audio. These requirements establish a minimum performance level for PCs that is comparable to low end consumer audio equipment. System designers are encouraged to exceed these minimum requirements, especially for consumer PCs.

Designers of integrated systems that include speakers are encouraged to ensure the availability of line out and/or USB ports as attach points for speaker upgrades.

Mobile PC Note

Most of the specifications and tests isolate half-duplex play or record performance. Additional attention should be paid to full-duplex systems with an embedded microphone and speakers, such as mobile PCs and multimedia monitors, where acoustic coupling can significantly degrade microphone performance.

For precise definitions of the terminology used in the following charts, please refer to the PCAQM and the WHQL test methodology papers cited earlier in this section.

PC 99 Audio Minimum Performance Requirements

Feature	Requirement	Value
Full-scale input voltage PCAQM section 2.1 WHQL test # TBD	FSIP (A-D-PC) line input	≥~~2.0 to 2~~3.0 Vrms (may require external voltage divider)
	FSIP (A-D-PC) microphone input	≥~~50 to 2~~100 mVrms
Full-scale output voltage PCAQM section 2.2 WHQL test # TBD	FSOP (PC-D-A) line output	≥1.0 ~~to 2.0~~ Vrms[5]
Analog pass-through ~~performance~~ (A-A) WHQL test #: TM001	Line input to line output	
	Frequency response (-3 dB)	20 Hz to 20.0 kHz[4]
	Dynamic range (SNR)	≥80 dB FS A[2]
	THD+N	≤–65 dB FS[3]
	Line input to speaker output with 8-ohm load	
	Frequency response (-3 dB)	20 Hz to 20.0 kHz[4]
	Dynamic range (SNR)	≥70 dB FS A[2]
	THD+N	≤–55 dB FS[3]
	Microphone input to line output	
	Frequency response (-3 dB)	100 Hz to 12.0 kHz
	Dynamic range (SNR)	≥70~~5~~ dB FS A[2]
	THD+N	≤–55 dB FS[3]

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PC 99 Audio Minimum Performance Requirements, continued

Feature	Requirement	Value
Digital playback (PC-D-A) for line output WHQL test # TM002	Frequency response (-3 dB) 44.1-kHz source material 48.0-kHz source material	 20 Hz to 17.6~~9~~ kHz[4] 20 Hz to 19.2~~0~~ kHz[4]
	Dynamic range (SNR)	≥80 dB FS A[1,2]
	THD+N	≤–65 dB FS[3]
Digital recording (A-D-PC) for line input WHQL test # TM003	Frequency response 44.1-kHz destination ~~material~~ 48.0-kHz destination ~~material~~	 20 Hz to ~~19~~ 17.6 kHz[4] 20 Hz to ~~20~~ 19.2 kHz[4]
	Dynamic range (SNR)	≥70~~5~~ dB FS A[2]
	THD+N	≤–60 dB FS[3]
Digital recording (A-D-PC) for microphone input PCAQM section TBD WHQL test # TBD	Frequency response (-3 dB) 22.05 kHz destination	 100 Hz to 8.8 kHz
	Dynamic range (SNR)	≥70 dB FS A[2]
	THD+N	≤–60 dB FS[3]
Line output cross-talk PCAQM section 2.7 WHQL test # TBD	Channel separation between left and right line out~~put~~ channels (measured at 10 kHz)	≥60~~5~~ dB[6]
Sampling frequency accuracy PCAQM section 2.9 WHQL test # TBD	Playback Record	0.1% 0.1%

[1] Decibels relative to full scale (FS), measured using "A weighting" filters.

[2] For mobile PCs, the dynamic range requirements are relaxed by 10 dB FS A.

[3] For mobile PCs, the THD+N requirements are relaxed by 10 dB FS.

[4] For mobile PCs, the required frequency response is 20 Hz to 15 kHz, measured using ~~6~~ 3 dB corners.

[5] For mobile PCs with 3.3 V audio subsystems, the required Full Scale Output Voltage for line output is ≥0.7 Vrms.

[6] For mobile PCs, the cross-talk requirements are relaxed by 10 dB FS.

5. Audio system provides support for basic data formats in full duplex

Required

The audio system must be capable of operating in half-duplex or full-duplex modes with both the input and output streams using 16-bit resolution at 8, 11.025, 16, 22.05, 32, 44.1, and 48 kHz.

For output, the built-in or external audio codec hardware must, at minimum, support 16-bit stereo at 44.1 and 48 kHz. For support of other sample rates (8, 11.025, 16, 22.05, 32 kHz, and so on.) and formats (mono, 8-bit, and so on), any combination of the operating system-provided software SRC/K mixer services and hardware is acceptable.

For input, the built-in or external audio codec hardware must, at minimum, support 16-bit stereo at 44.1 and 48 kHz. For support of other sample rates (8,

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11.025, 16, 22.05, 32 kHz, and so on.) and formats (mono, 8-bit, and so on), any combination of operating system~~OS~~-provided software SRC/format services and hardware is acceptable.

The kernel mixer operation is documented at the following URL:
TBD.

Note: The PC 99 audio hardware requirements support full bandwidth CD quality audio (16-bit stereo at 44.1 or 48 kHz). The continued use of 8-bit data for games and multimedia content is discouraged because higher SNR-per-bit alternatives, such as IMA-ADPCM or Indeo® audio software, are available at low system overhead.

6. Audio system supports full-duplex operation at independent sampling rates

Required

Voice recognition and audio/video conferencing require the audio system to simultaneously play back and record. Incoming and outgoing audio should be capable of operating at independent sampling rates. This requirement considers the entire system, including the possibility of USB speakers or microphones.

7. Analog microphone input meets PC 99 jack and circuit specifications

Required

PC 99 requirements include a more detailed specification for the analog characteristics of the microphone input jack. It will improve compatibility for applications such as speech recognition and speakerphone telephony or conferencing. Several companies, including developers of speech recognition software, microphones, audio codecs, sound cards, and PCs, have collaborated with Intel and Microsoft to produce this specification.

The specification enables users with electret or dynamic microphones to connect the device to their PC and achieve consistent results. These requirements also maintain compatibility with the installed base of microphones. See the recommendations for optimal speech recognition microphone performance in the PC 99 Advanced Recommendations section.

If the PC has an analog microphone input, it must meet the following specifications:

- Three-conductor 1/8" (3.5 mm) tip/ring/sleeve microphone jack with bias on the ring to support both three-conductor electret microphones or two-conductor dynamic microphones
- Minimum AC input impedance between tip and ground: 10 kOhm
- ~~Nominal~~ Maximum full scale input voltage (FSIP): ≥100 mV (100 mV = 0 dB FS)

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- Minimum full scale input voltage (FSIP): ≤10 mV (~~0 dB FS with~~ via software programmable ≥20 dB gain for low output microphones)~~20 dB gain)~~
- ~~Software selectable 20 dB gain for low output microphones~~
- Maximum 5.5~~0~~ V with no load, minimum 2.0 V with 1 mA load, DC bias for electret microphones
- Minimum bias impedance between bias voltage source and ring: 2 kOhm
- AC coupled tip~~: recommended analog 3 dB rolloffs at 60 Hz and 15 kHz~~

~~Delivers a digitized input signal with >70 dB FS A weighted Dynamic Range (SNR) and <-60 dB FS unweighted Total Harmonic Distortion (THD+N). See also PC 99 Audio Performance Requirements~~

It is recommended that the PC analog microphone input also meet the following specifications:

- Minimum full scale input voltage (FSIP): 3 mV (via software programmable 30 dB gain for low output microphones)
- The AC-coupled tip is recommended to implement analog (external to ADC) 3 dB rolloffs at 60 Hz and 15 kHz

Note: These specifications are designed to ensure that when recording from the mic input at 22.050 or 44.1 kHz, the audio system delivers a digitized ≥8.8 kHz bandwidth input signal with ≥70 dB FS A weighted Dynamic Range (SNR) and ≤-60 dB FS unweighted Total Harmonic Distortion (THD+N). See also PC 99 Audio Performance Requirements.

8. Audio system reports sample position for stream synchronization
Required

The driver must be capable of returning an accurate indication of the current position of the buffer being rendered. Sample accuracy is in relation to the samples given to the codec. Accurate reporting of the current position in the buffer being rendered means reporting the position within 1 ms. This requirement applies for both compressed and uncompressed data.

For information about WDM device driver support for streaming capabilities, see the Windows NT 5.0 DDK. See also the related articles available on the web at http://www.microsoft.com/hwdev/desinit/.

9. Audio system connectors are labeled with icons as defined for PC 99
Required

To reduce user confusion, the external connections must use a consistent set of symbols based on the standard artwork defined in the “Icons” appendix in the References part of this guide.

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Advanced Audio Recommendations

This section outlines the future direction of PC audio. It offers a view of the market requirements to come for PC audio, describing a number of directions that the industry is taking.

10. Audio system provides sufficient externally accessible inputs and outputs
Recommended

At a minimum, the audio system should have the following analog audio connections:

- A monaural microphone input and/or stereo line input
- Stereo line-level output and/or headphone output

USB and IEEE 1394 ports provide the ability connect high quality digital audio input or output devices.

11. Microphone meets performance recommendations for PC 99 speech-recognition microphones
Recommended

To maximize performance of speech recognition applications, PC 99 has recommendations for speech-recognition microphone performance. Several companies, including developers of speech recognition software, microphones, audio codecs, sound cards, and PCs, have collaborated with Intel and Microsoft to produce this specification.

This specification represents a group consensus of the optimal characteristics for an electret microphone used for speech recognition and should enable developers of speech recognition software to provide the PC OEM or retail customer with a list of devices designed to work with the PC 99 mic input jack.

These requirements maintain compatibility with a majority of the installed base of sound cards and audio enabled motherboards. For more information about the microphone jack requirements, see the Audio Performance and Feature Requirements section.

A “PC 99 speech-recognition microphone” is defined as follows:

- Close speaking design (within 4 inches of the speaker’s mouth)
- Full scale output voltage: 100 mV (0 dB FS)
- Three-conductor 1/8" (3.5 mm) tip/ring/sleeve plug with tip and ring internally shorted together to carry the audio signal and bias voltage. The sleeve carries the ground.
- Operating bias voltage from 2.0-5.0 VDC with a maximum current drain of 1 mA

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- Capable of sustaining a maximum voltage of 10 VDC on tip or ring without damage

It is recommended that a PC 99 speech-recognition microphone also meet the following specifications:

- Frequency response:
  - ±5 dB from 100 Hz to 10 kHz
  - ± 3 dB from 300 Hz to 5 kHz
  - 0 dB at 1 kHz
- Minimum sensitivity of -44 dB relative to 1V/Pa
- Total Harmonic Distortion (THD+N) < -34 dB FS
- Noise cancellation with the following minimums:

  19 dB at 250 Hz
  14 dB at 500 Hz
  9 dB at 1000 Hz
  4 dB at 2000 Hz
  0 dB at 3500 Hz
- Maximum wind noise sensitivity of –45 dB with 0 dB = 100 mV. (Measured with wind speed of 1m/s at the microphone element.)
- Maximum output impedance of 1 kOhm (using a 1 kHz full-scale test tone with 2.0 VDC bias)

12. Audio system provides hardware or software support for the Downloadable Sounds specification

Recommended

Support for DLS as defined by the MIDI Manufacturers Association is recommended. For more information, see *DLS Specification, Version 1.0* or later, at http://www.midi.org.

13. Audio system supports AEC reference inputs

Recommended

Full-duplex internal or external audio codecs that introduce additional digital or analog audio sources into the final mix are recommended to support simultaneous capture of microphone and AEC reference inputs. One analog-to-digital converter (ADC) is used to capture the microphone input, and another ADC is used to capture a monophonic representation of final output mix, which includes all digital and analog sources.

It is possible to use a single stereo ADC to capture the two monaural streams. The AEC reference should be time-synchronized and available at the same sample rate as the microphone input.

For more information, see Section 6.2 of the Audio Codec ’97 specification from Intel Corporation, which describes one possible implementation.

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14. Audio system provides hardware filtering of 3-D localization filters
Optional

For those solutions that provide hardware acceleration of 3-D filters, support for eight separate audio sources is suggested, especially for Entertainment PCs.

15. CD, DVD, and broadcast audio playback meet PC 99 requirements
Required with DVD Video

These recommendations are specified to ensure quality playback of MPEG-2 audio from any source, including DVD, digital broadcast or satellite systems, hard drives, and so on. The goal for DVD and other A/V playback is to ensure that the end-user experience is the same or better than from a stand-alone DVD player.

For those PCs that support software or hardware decoding and playback of DVD-Video or MPEG-2 video, the audio decoder must be capable of supporting the following formats:

- Support for one or both of the following formats is required, depending upon the local requirements for DVD audio:
  - AC-3 (Dolby Digital) less than or equal to 5.1 channels, at 48 kHz less than or equal to 384 Kbps.
  - MPEG-2 multichannel less than or equal to ~~7~~5.1 channels, at 48 kHz less than or equal to 912 Kbps.
- MPEG-1 Layer 2 stereo, at 44.1 and 48 kHz less than or equal to ~~384~~ 448 Kbps.
- LPCM less than or equal to 8 channels, 16-bit, 20-bit, and 24-bit at 48 or 96 kHz less than or equal to 6.144 Mb/s.

Note: Conversion to 48-kHz 16-bit stereo is acceptable when the content exceeds the available resolution, sampling rates, or number of output channels.

16. Audio system provides consistent volume levels for different devices
Optional

In cases where each audio channel is set to the same position on the Windows mixer panel, it is suggested that each channel provide a comparable volume level. Users should not need to have radically different settings on the control panel to balance the relative volume of each audio channel.

17. Audio system does not provide a DB-15 analog joystick/MIDI port
Recommended

USB offers substantial benefits in connecting joysticks and MIDI adapters. Continued support for the DB15 analog gameport and legacy peripherals, such as polled analog joysticks, adds cost, impacts ease of use, and degrades overall system performance.

~~This recommendation will become a requirement in the next version of these guidelines.~~

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PC 99 Design for Audio

This section summarizes requirements related to the PC 99 design initiatives as defined in Part 1 of this guide.

Plug and Play for Audio

The items in this section are requirements for all audio components.

18. Each device has a unique Plug and Play device ID
Required

Each bus-specific device must have a Plug and Play device ID for the bus it uses, as defined in Part 3 of this guide. For example, a PCI device must comply with PCI 2.1 requirements and also provide a Subsystem ID and Subsystem Vendor ID as defined in the "PCI" chapter in Part 3 of this guide. As another example, a USB device must provide a unique ID as defined in the *Universal Serial Bus Specification, Version 1.0* or later.

Note: Each separate device or function enumerated by the BIOS on an audio adapter must have a separate Plug and Play device ID and separate resource configuration. If a game port or CD-ROM interface is supplied, resources must be allocated in addition to those required for the audio device. Such devices must also have independent dynamic disable capabilities. For complete information about requirements for multifunction cards, see the "PC 99 Basic Requirements" chapter in Part 2 of this guide.

19. Automatic resource assignment and dynamic disable capabilities are supported
Required

The system must be capable of automatically assigning, disabling, and relocating the resources used by this device when necessary, using the method required for the related bus class. All configuration settings must be capable of being made through software, with no system reboot required.

When the end user changes this device or adds it to the system, setting resource assignments must not require changing jumpers or switches on either the adapter or the system board. In the event of an irreconcilable conflict with other devices on the system, the system must be able to disable the device in order to prevent the system from stalling. The device must not claim any resources while disabled.

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Bus Design for Audio

This section defines the requirements for bus-specific design for PC 99 audio.

Requirements for PCI Audio Devices

For audio devices that connect to the PCI bus, the following requirements apply.

20. PCI device conforms to PCI 2.1 and additional PC 99 requirements
Required

If the device uses PCI, it must meet the requirements defined in the "PCI" chapter in Part 3 of this guide, including requirements for providing a Subsystem ID and Subsystem Vendor ID and for complying with PCI 2.1.

21. PCI device supports initiator, target, and block transfer
Required

For complete implementation details, see PCI 2.1.

Full-duplex audio sample transport must be supported using separate PCI bus mastering hardware for playback and capture sample streams.

It is desirable for sample transport mastering hardware to support burst capabilities in order to read or write multiple samples within the same PCI bus transaction. This will lessen the impact of sample transport on other agents in the system, which will have a positive effect on the system's responsiveness.

22. PCI device supports non-Dword-aligned audio buffers
Required

To achieve optimal efficiency and latency when transferring audio data, the hardware must move the PCM audio buffer directly between memory and the audio device *without introducing buffer copies to re-align the data*. Although the recommended programming practice is to use Dword-aligned, Dword-multiple length buffers, it is not possible to guarantee that all audio buffers will conform. Depending on the data format, the following cases can occur:

- The first sample of the audio buffer might not start on a DWORD boundary
- The last sample of the audio buffer might not end on a DWORD boundary

PC 99 recommends that all PCI audio devices support buffers with arbitrary byte alignments and lengths.If a PCI device does not support arbitrary byte alignment and length, it must support buffer alignments and lengths which correspond to the smallest supported sample size it accepts.

- Example 1: a device supports 8-bit monaural audio. This data could appear in memory on byte boundaries. The transfer length could be an integer number of bytes. To meet PC 99 requirements, this device must correctly play audio data that is aligned on a byte boundary and has a length that is an integer number of bytes. It must not play non-audio data that either precedes or

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follows the audio data, nor can its device driver copy the audio data to a second buffer with an alignment or length of larger granularity, then play the second buffer through the device.

~~To meet PC 99 requirements, this device must support byte alignment and be able to transfer any number of bytes directly from memory into the PCI device.~~

- Example 2: a device supports only 16-bit audio formats. To meet PC 99 requirements, this device must correctly play audio data that is aligned on a 16-bit boundary and has a length this is an integer number of 16-bit words. It must not play non-audio data that either precedes or follows the audio data, nor can its device driver copy the audio data to a second buffer with an alignment or length of larger granularity, then play the second buffer through the device.~~To meet PC 99 requirements, this device must be able to accommodate the data on 16-bit word boundaries and transfer an integer number of 16-bit words~~.

Note: For maximum efficiency, Microsoft recommends that audio buffers allocated by DirectX clients, WDM kernel services clients, and WDM minidrivers be DWORD aligned and DWORD multiples in length whenever possible.

23. PCI device does not use ISA-based resources in Windows or an MS-DOS box

Required

In Windows and an MS-DOS box, the PCI device must not allocate or use ISA IRQs, DMAs, or hard-coded I/O locations. The BIOS and Windows driver must not contain any options to select the use of ISA resources for the audio device.

If a device supports real-mode operation, the only acceptable manner for acquiring ISA resources is to use a real-mode configuration utility.

24. PCI device is digital ready

Required

In order to transfer digital audio to USB or IEEE 1394 devices, all digital audio data created in the PC must be available to the operating system for mixing and streaming. All PCI audio devices must be able to route the final mix of all digital audio data created or processed on-chip to the host using bus master transfers.

~~V5upport for capture and inclusion of internal analog resources in the final mix is desirable but not required. CD-ROM drives that support direct reading of Red Book data through the primary interface are required.~~

For example, a PCI audio device provides HRTF 3-D filtering and wave-table synthesis. After mixing all of the separate 3-D sources and wave-table channels down to a single stereo stream, the device transfers the data to host memory.

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Requirements for USB Audio Devices

For audio devices that connect to a USB port, the following requirements apply.

25. Audio meets USB specification and USB audio device class specification
Required

The device must comply with *Universal Serial Bus Specification, Version. 1.0* or later, and the USB device class specification for audio. This ensures that all Plug and Play requirements are met and that drivers provided with the operating system support this device.

26. USB audio device uses MMHID for control of basic functions
Required

If the USB audio device implements a volume or pan control, it must use the MMHID protocol to communicate these changes to and from the host.

Requirements for IEEE 1394 Audio Devices

For audio devices that connect to the IEEE 1394 bus, the following requirement applies.

27. Audio meets PC 99 requirements for IEEE 1394
Required

For requirements related to IEEE 1394 peripherals, see the “IEEE 1394” chapter in Part 3 of this guide.

Power Management for Audio

This section summarizes the power management requirements for audio components.

28. System and device comply with PCI bus power management specification
Required

PCI-based audio controllers must comply with the *PCI Bus Power Management Specification, Revision 1.0* or later (PCI PM). Any PCI add-on audio device must comply with PCI PM. Audio devices implemented on the system board must comply fully with the ACPI 1.0 specification.

29. Audio device complies with device class power management reference specification
Required

The *Audio Device Class Power Management Reference Specification, Version 1.0* or later, provides definitions of the OnNow device power states (D0–D3) for these devices. The specification also covers device functionality expected in each power state and the possible wake-up event definitions for the class. Implementation of power states D0, D2, and D3 is required. Other power states are optional.

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Device Drivers and Installation for Audio

This section summarizes requirements for audio device drivers.

30. Device drivers and installation meet PC 99 requirements
Required

The manufacturer does not need to supply a driver for a device if the device passes PC 99 compliance testing using a driver provided with the operating system. If the manufacturer supplies the drivers, the requirements for the device drivers and installation are defined in the “PC 99 Basic Requirements” chapter in Part 2 of this guide. The basic requirements include driver support for unattended installation and Help file support if special driver parameters are used.

31. Audio meets PC 99 requirements for WDM driver support
Required

All audio devices must have drivers that use the 32-bit WDM architecture exclusively. Audio devices must not use VxDs. The manufacturer can either supply a WDM driver with the audio device or rely on a WDM driver provided with Windows and Windows NT. For information, see the Windows NT 5.0 DDK.

32. Applications provided with device meet Win32 requirements
Required

Any Windows-based applications provided with the device must meet software compatibility requirements as defined in the Microsoft Platform SDK.

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Audio References

The following represents some of the references, services, and tools available to help build hardware that is optimized to work with Windows operating systems.

Advanced Configuration and Power Interface Specification, Revision 1.0
http://www.teleport.com/~acpi/

Audio '98 Roadmap, Audio Codec '97 Component Specification, and *Audio Codec '97 Design Guide* papers
Intel Corporation
http://developer.intel.com/pc-supp/platform/aud98/

Audio design for Windows operating systems white papers
http://www.microsoft.com/hwdev/devdes/

Audio Device Class Power Management Reference Specification, Version 1.0
http://www.microsoft.com/hwdev/onnow.htm

Downloadable Sounds (DLS) specification
MIDI Manufacturers Association
Fax: (714) 736-9775
E-mail: mma@midi.org
http://www.midi.org

Personal Computer Audio Quality Measurement Definitions
by Dr. Steven Harris and Cliff Sanchez, Crystal Semiconductor
http://www.crystal.com/new/papers/meas.htm

PCI Local Bus Specification, Revision 2.2 (PCI 2.2)
PCI Bus Power Management Specification, Revision 1.0 (PCI PM)
http://www.pcisig.com

Plug and Play specifications
http://www.microsoft.com/hwdev/specs/

Universal Bus Specification, Version 1.0
USB device class specifications
http://www.usb.org

WDM device driver support white papers
http://www.microsoft.com/hwdev/desinit/

Windows DDK, Windows NT DDK, DirectX DDK, and Microsoft Platform SDK
MSDN Professional membership

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Checklist for Audio Components

If a recommended feature is implemented, it must meet the PC 99 requirements for that feature as defined in this document.

Consumer PC 99	Office PC 99	Entertainment PC 99
1. PC system includes PC 99 audio capabilities		
Recommended	*Recommended*	*Required*
2. Audio device does not connect to ISA bus		
Required	*Required*	*Required*
3. Audio device does not use legacy hardware interfaces in an MS-DOS box		
Required	*Required*	*Required*
4. Audio performance meets PC 99 requirements		
Required		
5. Audio system provides support for basic data formats in full duplex		
Required		
6. Audio system supports full-duplex operation at independent sampling rates		
Required		
7. Analog microphone input meets PC 99 jack and circuit specifications		
Required		
8. Audio system reports sample position for stream synchronization		
Required		
9. Audio system connectors are labeled with icons as defined for PC 99		
Required		
10. Audio system provides sufficient externally accessible inputs and outputs		
Recommended		
11. Microphone meets performance recommendations for PC 99 speech-recognition microphones		
Recommended		
12. Audio system provides hardware or software support for the Downloadable Sounds specification		
Recommended		
13. Audio system supports AEC reference inputs		
Recommended		
14. Audio system provides hardware filtering of 3-D localization filters		
Optional		
15. CD, DVD, and broadcast audio playback meet PC 99 requirements		
Required with DVD Video		
16. Audio system provides consistent volume levels for different devices		
Optional		
17. Audio system does not provide a DB-15 analog joystick/MIDI port		
Recommended		
18. Each device has a unique Plug and Play device ID		
Required		
19. Automatic resource assignment and dynamic disable capabilities are supported		
Required		

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20. PCI device conforms to PCI 2.1 and additional PC 99 requirements
Required

21. PCI device supports initiator, target, and block transfer
Required

22. PCI device supports non-Dword-aligned audio buffers
Required

23. PCI device does not use ISA-based resources in Windows or an MS-DOS box
Required

24. PCI device is digital ready
Required

25. Audio meets USB specification and USB audio device class specification
Required

26. USB audio device uses MMHID for control of basic functions
Required

27. Audio meets PC 99 requirements for IEEE 1394
Required

28. System and device comply with PCI bus power management specification
Required

29. Audio device complies with device class power management reference specification
Required

30. Device drivers and installation meet PC 99 requirements
Required

31. Audio meets PC 99 requirements for WDM driver support
Required

32. Applications provided with device meet Win32 requirements
Required

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